

## Productivity, Mortality, and Movements of *Nene* in the Ka'u Desert, Hawaii Volcanoes National Park, 1981–1982<sup>1</sup>

C. P. STONE,<sup>2</sup> H. M. HOSHIDE,<sup>2</sup> and P. C. BANKO<sup>2</sup>

ALTHOUGH THEIR FOSSILIZED BONES have been found in lowland areas of other Hawaiian islands (Olson and James 1982), Hawaiian geese or *nene* (*Nesochen sandvicensis*) are now limited largely to mid and high elevation sites (1200–2100 m or 4000–7000 ft) on the islands of Hawaii and Maui. As late as the early 1900s, *nene* were thought to breed below 400 m (1300 ft) along much of the southeastern (Puna and Ka'u districts) and western (Kona and Kohala districts) coasts of Hawaii (Henshaw 1902, Perkins 1903). Use of lowland areas by *nene* later in the 20th century (until the 1940s) was summarized by Baldwin (1945).

*Nene* currently on the island of Hawaii originated from wild pairs and are thus unbanded, were produced by a captive breeding flock at the Pohakuloa Breeding Facility of the Hawaii State Department of Land and Natural Resources (DLNR), or were derived from a small breeding flock at Hawaii Volcanoes National Park (HAVO). Birds from the two propagation projects are marked with colored plastic bands. The DLNR project began in 1949, and over 1338 birds have been released in state sanctuaries (Keauhou, Kahuku, or Keauhou II) or Kipuka Ainahou through 1982 (Figure 1). The HAVO project began in 1974, and 57 birds have been released from 0.3–3.0 acre pens (Figure 2) through 1982 at low and mid elevation sites (Banko 1982).

In 1976, DLNR began to reduce the number of releases from Pohakuloa to test the survival of wild birds (Walker 1982). This, combined with a series of dry years and low *nene* productivity, apparently reduced use of traditional Mauna Loa breeding sites such as Keauhou Sanctuary and HAVO areas above 1200 m (4000 ft). No birds have been known to nest in

higher altitude HAVO areas since 1979. *Nene* nesting activity in the barren Ka'u Desert near Halemaumau Crater (1050 m or 3500 ft) was evident in 1981–1982, however. In this paper, we report on nesting success, mortality, and movements of *nene* in that area in 1981–1982, and include some additional nesting season information for birds breeding below 800 m (2600 ft).

### STUDY AREA

The Ka'u Desert comprises one of six vegetation types within the Submontane Seasonal Zone which in turn is one of six major ecosystems in HAVO (Mueller-Dombois 1976). The desert is characterized by very sparse, xerophytic vegetation, a shifting ash substrate, sulfur effluent from Halemaumau Crater, moderate to high winds, and drier summers than the remainder of the zone. The central Ka'u Desert contains nearly barren lava with sparse, dwarf *Styphelia*, *Dodonaea*, and *Metrosideros* (Doty and Mueller-Dombois 1966). Broomsedge (*Andropogon*) savannah and a large area covered with *Metrosideros*–*Andropogon* and native shrubs dominate south of the desert, although the exotic *Melinis minutiflora* now has invaded many areas. To the north, open but increasingly dense *Metrosideros* forests with taller trees and more frequent lichens occur. Rainfall to the west (Kapapala Ranch) is similar to that in the desert except for a less pronounced summer drought (Doty and Mueller-Dombois 1966).

### METHODS

#### *Nesting Studies*

We searched for active *nene* nests on foot, on horseback, and, on one occasion, from a

<sup>1</sup> Manuscript accepted 17 May 1983.

<sup>2</sup> National Park Service, Hawaii Volcanoes National Park, Hawaii 96718.

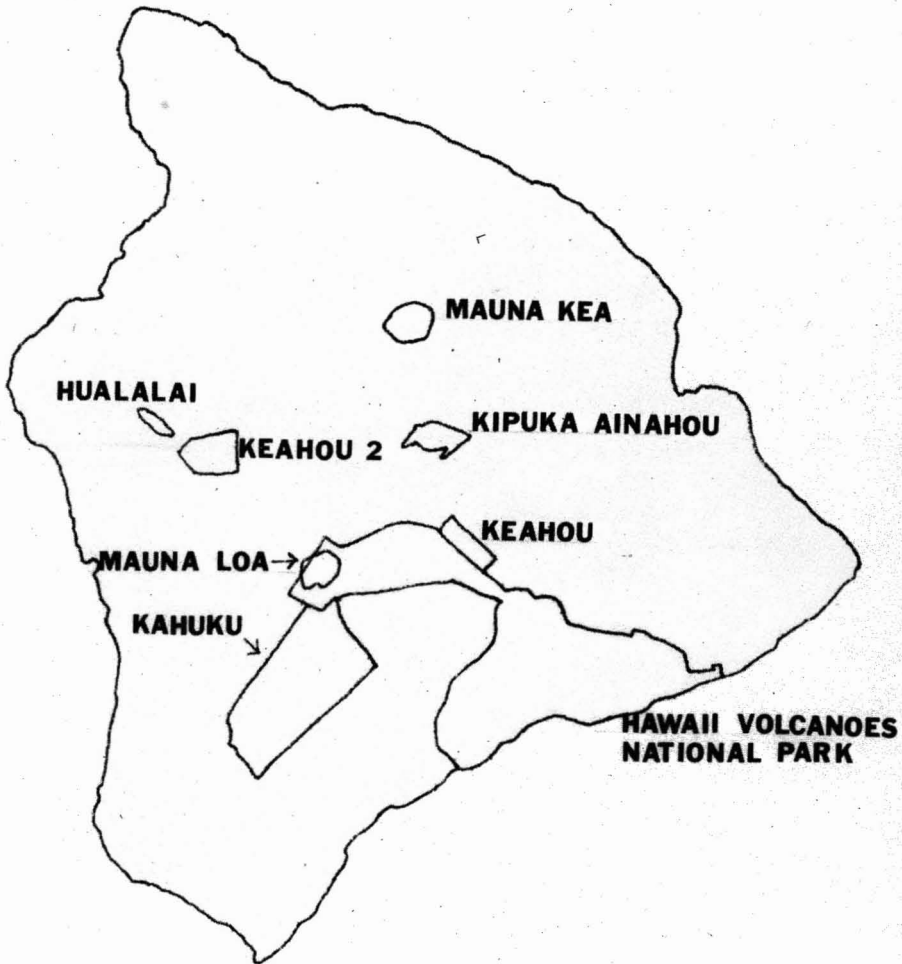


FIGURE 1. Relationships of state sanctuaries (Keauhou, Keauhou II, and Kahuku) to Hawaii Volcanoes National Park and three major volcanoes (Hualalai, Mauna Loa, and Mauna Kea) on the island of Hawaii.

helicopter. A trained bird dog increased our efficiency in locating birds and nests, as did the use of groups of people working together to cover extensive tracts systematically. Cues used to find nests were known locations of nests in past years, observations made by other park personnel, and locations of territorial birds. Some areas that seemed promising despite lack of cues, but had not been checked previously during *nene* breeding season, were also covered.

Once nests were located, we tried to avoid

disturbing birds more than once per week. Nest contents were checked by gradually approaching until females slipped away or got up and walked off. Some territorial males and females were observed through 20–60 × zoom spotting scopes to help us determine behavior at the nest and pinpoint hatching times.

#### *Predator Indices*

Four mongoose (*Herpestes auropunctatus*) tracking tunnels were placed 20–100 m from

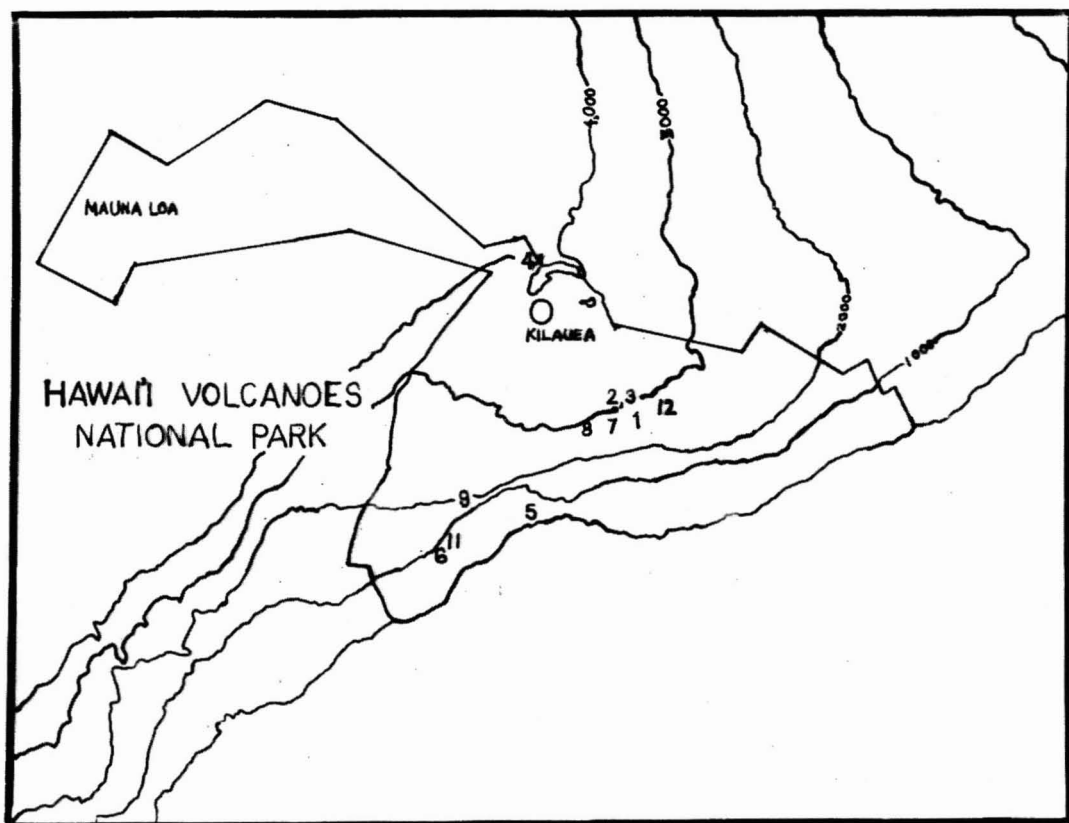


FIGURE 2. *Nene* release pens in Hawaii Volcanoes National Park. Numbers 1–10 = pen numbers, 11 = goat enclosure, and 12 = Kipuka Kahali'i.

nests to determine predator activity. Each quonset-shaped tunnel was 65 cm in length with entrances  $14 \times 14$  cm at each end. One dried dog food pellet was placed between two  $12 \text{ cm}^2$  rubber baseboard tiles and tiles were sprayed with a saturated solution of ethyl alcohol and talcum powder (Lieberman 1973) to record tracks. Tunnels were checked once per week for tracks at the same time the nests were checked.

Four Tomahawk live traps (40 cm long with  $14 \text{ cm}^2$  entrance) replaced tracking tunnels after nests had hatched or failed. Live traps were baited with pork fat and operated for seven days to supplement predator indices from tracking tunnels. In addition, four traps were set in the same pattern (i.e., as if surrounding a nest) at each of three randomly chosen stations in three locations in *nene*

breeding range. Ka'u Desert, upper Ainahou Ranch pasture (about 900 m or 3000 ft), and lower Ainahou Ranch (about 750 m or 2500 ft) were used for these tests. Distances and directions from access roads to each of the three sample sites were chosen randomly for each of the three areas. Trapping was conducted for two 4-day periods in each location to determine predator activity.

#### *Movement Studies*

Three adult ganders were captured in a hand net and fitted with harnesses and SM<sub>1</sub> solar NICAD transmitters (AVM Instrument Co., Ltd., Dublin, California)<sup>3</sup> shortly before

<sup>3</sup> Reference to product does not constitute endorsement.



FIGURE 3. Solar transmitter on adult nene gander.

or after their goslings hatched (Figure 3). Harnesses of teflon-coated, braided nylon were threaded through holes in transmitter potting material, tied and clipped together at the gander's breast, and wrapped with electrical tape at knots and metal clip. The first transmitter was attached with small diameter

surgical tubing because the more permanent braided nylon had not arrived. Cloth pads were attached to bases of the 164 MHz solar transmitters to reduce friction. Harness and transmitter together weighed less than 30 g (1.5–2.0% of adult goose weight). In one case, a transmitter was attached to an adult female

TABLE 1  
NENE NESTING SUMMARY, 1981–1982, HAWAII VOLCANOES NATIONAL PARK

NEST LOCATION	NUMBER OF NESTS	EGGS LAID	EGGS HATCHED	EGGS INFERTILE	LARGE EMBRYOS	DEAD GOSLINGS	YOUNG FLEDGED
Ka'u Desert	8	21	9	7*	5†	7	2
Lowlands‡	3	10	10	0	0	7	3
TOTAL	11	31	19	7	5	14	5

\* Six of these in deserted nests.

† Four of these in deserted nests.

‡ 800 m elevation or less.

with goslings after the instrumented male disappeared. AVM LA-12 receivers with three-element, hand-held Yagi antennae were used to track birds.

We attempted to obtain fixes on instrumented families at least once per week during the study. For the first 2 weeks after hatching, our goal was to obtain fixes at least once per day. Once families were located, we tried to sight all birds in the family group quickly and leave the area as soon as possible. This was especially true when goslings were small. After onset of feather molt, adults were captured at least once to determine molt progression. Compass directions from observation sites to local landmarks were taken and intersections of bearings were used to plot fixes on 1:24,000 U.S. Geological Survey topographic maps.

## RESULTS

### *Productivity and Recruitment*

Eleven active nests were located at elevations ranging from less than 300 m (1000 ft) to 1050 m (3500 ft). Of 31 eggs laid ( $\bar{x}$  = 2.82 eggs/nest, mode = 3, range = 2–4), 19 (61.3%) hatched, and 5 (16.1%) resulted in fledged (flying) young (Table 1). Two (9.5%) of the 21 Ka'u Desert eggs and 3 (30.0%) of the 10 lowland (<800 m or 2600 ft) eggs resulted in fledged young. However, two of the three lowland nests were in areas somewhat protected from predation (*nene* breeding pen 8 and Kukalau'ula goat enclosure). Five of the eight Ka'u Desert nests were deserted: two

after nests were flooded; at least one because eggs were infertile; one possibly because two young died shortly after hatching; and one for unknown reasons (eggs found after nesting season).

The contribution of HAVO-released birds to the park breeding population is fairly large. Of the 54 birds in breeding-age pairs in the park in summer 1981, 35 (64.8%) originated from the HAVO release program, 4 (7.4%) from the state releases, and 15 (27.8%) were produced in the wild (Table 2). In the 1980–1981 breeding season, eight pairs were known to have attempted nesting, and 11 (68.7%) of the birds involved were HAVO releases. In the 1981–1982 season, only 8 (44.4%) of the 18 birds (nine pairs) known to have attempted nesting were HAVO releases. Four (22.2%) were state releases and six (33.3%) were produced in the wild.

Only 12 (44.4%) of the 27 pairs in the park were known to attempt breeding in one of the two breeding seasons, and only 4 pairs (14.8%) were known to have attempted nests both years. Two of these pairs nested in the lowlands, and both females were HAVO-released birds (Table 3). The other two pairs nested in the Ka'u Desert; one female was unbanded and one was a state bird from Kipuka Ainahou.

### *Predation*

Predator activity in the desert was nearly nonexistent in 1981–1982 (Table 4). In 984 tracking-tunnel days, no mongoose tracks were observed. No mongooses were captured

TABLE 2  
ORIGIN OF BREEDING *Nene* IN HAWAII VOLCANOES NATIONAL PARK

	NPS RELEASES		STATE RELEASES		UNBANDIED		TOTAL
	M	F	M	F	M	F	
Sighted in 1981	17	18	2	2	8	7	54
Attempted breeding, 1980-81	5	6	1	1	2	1	16
Attempted breeding, 1981-82	3	5	2	2	4	2	18
Attempted breeding, both seasons	2	2*	1	1	1	1	8

\* Lowland birds.

TABLE 3  
COMPARISON OF RELEASE SITES OF *Nene* FEMALES WITH NEST SITES CHOSEN IN HAVO, 1980-1982

	1980-1981		1981-1982	
	RELEASE	BREEDING	RELEASE	BREEDING
Lowlands	Pen 3 Pen 5 Pen 6 Pen 6 Pen 6 Pen 8	Ainahou Ranch Kipuka Kahali'i? Pen 6 Pen 9 Goat enclosure Pen 8	Pen 8   Pen 6 Pen 8	K. Kahali'i   Goat enclosure Pen 8
Ka'u Desert	K. Ainahou Unknown	Kilauea Area Kilauea Area	K. Ainahou Unknown Hualalai Pen 3 Pen 1, 4	Kilauea Area SW Rift SW Rift Ka'u Trail Ka'u Trail

TABLE 4

INDICES TO MONGOOSE POPULATIONS IN *Nene* BREEDING HABITAT, HAWAII VOLCANOES NATIONAL PARK, 1981-1982

LOCATIONS AND DATES	TRACK OR TRAP DAYS	MONGOOSES CAPTURED/TRACKED	MONGOOSES PER TRAP/TRACK DAY
Ka'u Desert <i>nene</i> nest sites (12/21/81-1/15/82)	984	0	0.00*
Ka'u Desert <i>nene</i> nest sites (2/17-3/5/82)	140	0	0.00
Ka'u Desert random locations (3/9-3/12 and 3/16-3/19/82)	192	1	0.01
Upper Ainahou Ranch random locations (3/16-2/19 and 3/23- 3/26/82)	162	5	0.03
Lower Ainahou Ranch random locations (4/06-4/09 and 4/13- 4/16/82)	186	1	0.01

\* Tracking station data; animal(s) not removed from population.

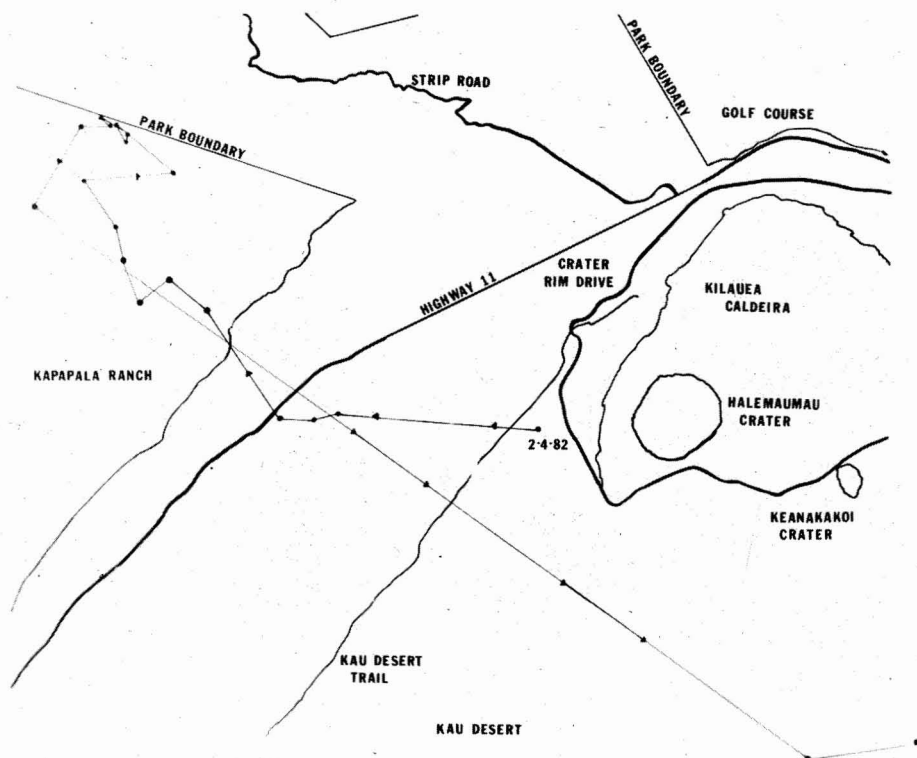


FIGURE 4. Movements of Family 11 (11 January to 20 May 1982).

during 140 live trap days. In contrast, 192 tracking-tunnel days around a lowland nest produced four signs of mongooses (0.02/tracking day), and 28 trap days around the same nest produced one mongoose (0.04/trap day). Randomly chosen trap sites produced a somewhat higher trapping index (0.01) in the Ka'u Desert than those around nests. The trap index from a low elevation (700 m or 2300 ft) *Melinis* meadow was lower (0.01) than that from an *Andropogon* grassland near 'ōhi'a woods (0.03) at a somewhat higher elevation (800 m or 2700 ft). Catches in all traps were low and replicates were not run, so statistical analyses were not performed on these data.

#### Movements of Family 11

The gander in Family 11 was instrumented 11 January, the day after the eggs hatched. He was previously an unbanded male mated with a 6-year and 9-month old (as of 1/1/82) state

female initially released in the Keauhou II Sanctuary. These birds nested along the Southwest Rift Zone (near Halemaumau pit) in 1980–1981, and young goslings were observed with them.

The longest minimum day to day movement (988 m or 0.6 mi) in the first 10 days after hatching occurred when the two goslings were 5 days old (Figure 4). This was followed by a movement of only 0.3 km (0.2 mi) along Highway 11 on day 6. The family reached the pastures of Kapapala Ranch when the goslings were 8 days old (19 January) and foraged in areas at elevations of 1100–1350 m (3700–4400 ft) until at least 8 February (goslings 27 days old). At this time we lost contact with them. The goose and two goslings were next observed March 9 (56th day) in the Ka'u Desert without the gander, 3.4 km (2.1 mi) from the last sighting. We were able to find the female (still with two goslings) through use of a bird dog and instrumented her 8 April (86th

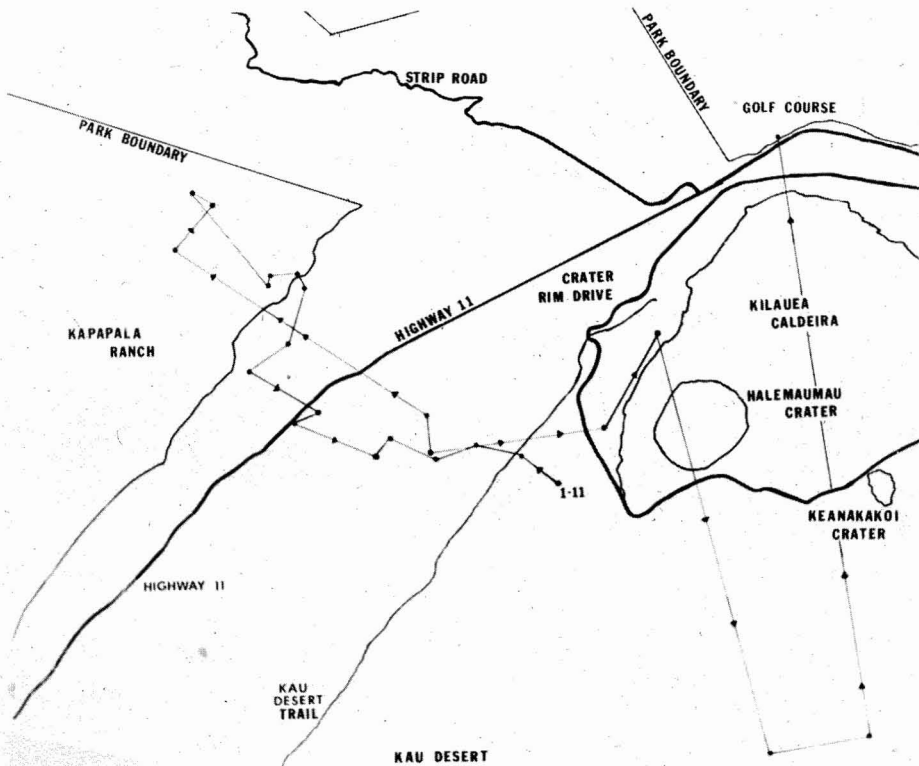


FIGURE 5. Movements of Family 4 (4 February to 20 May 1982).

day). At this time she was flightless (due to molt) with a prominent keel (breastbone). On 4 May (112th day) she was located 5.8 km (3.6 mi) to the southeast. By 20 May (128th day) she and the two fledglings had moved back 6.5 km (4 mi) toward Kilauea Caldera, and she was seen with the gander from Family 5. On 28 May (136th day) she was seen on the Volcano Golf Course with the Family 5 gander and two fledglings, 3.7 km (2.3 mi) from the 20 May location. She spent much of the summer in a golf course flock with both the goose and gander from Family 5.

#### *Movements of Family 4*

The gander in Family 4 was instrumented 4 February, one day after the eggs hatched. He was a 7-year and 1-month old state male released at Kipuka Ainahou and mated with an unbanded female. This pair nested in 1979–

1980 and 1980–1981 in the vicinity of Kilauea Caldera, and young goslings were seen.

Adults and young in Family 4 were near the nest on the morning after hatching (Figure 5). While we were attaching the transmitter to the gander, goose and goslings moved east about 0.2 km (0.1 mi). We carried the instrumented gander to this location and released him near the family. He immediately joined the others and did not take flight. However, the family moved 2.7 km (1.7 mi) that day (goslings were 1-day-old). Movement on day 2 was only 0.4 km (0.2 mi), but once across Highway 11 on day 3, the family moved 2.0 km (1.3 mi) and reached Kapapala Ranch. This family wandered about the northeastern part of Kapapala Ranch for several days at elevations of 1200–1350 m (3950 to 4750 ft). We lost track of them during a period of heavy rains for 9 days. When contact was reestablished 21 February (18th day) only one gosling remained. The family used an area on the



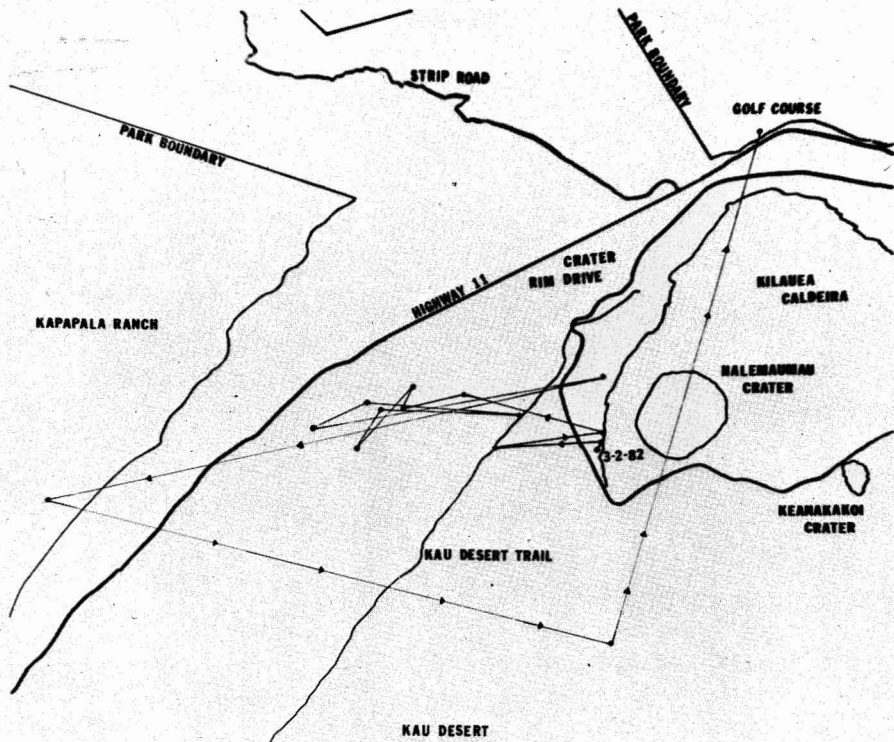


FIGURE 6. Movements of Family 5 (2 March to 20 May 1982).

ranch at 1375–1400 m (4500–4600 ft) until 23 March but had moved southwest 1.1 km (0.7 mi) by 31 March (56th day). When next located 8 April (64th day), they had moved 11.1 km (6.9 mi) southeast, the adults were flightless due to molt, and keels were prominent. On 13 April (69th day), the remaining gosling was missing, and the adults were 1.3 km (0.8 mi) to the east. By 4 May (90th day), they had moved in a westerly direction 5.6 km (3.4 mi), and by 7 May (93rd day), an additional 1.3 km (0.8 mi). On May 20 (106th day), the male was discovered dead in a small *kīpuka* (an island of older vegetation surrounded by lava or younger vegetation) near Crater Rim Road, 2.4 km (1.5 mi) to the east. Since the female was unbanded, observations on this family ended.

#### *Movements of Family 5*

The gander from Family 5 was instrumented 25 February, but the three eggs did

not hatch until 2 March. The male was a 2-year-old released from Pen 9 (Kipuka Ahiu) in the HAVO lowlands. The female was 5-years-10 months-old, released by the state at Kipuka Ainahou. The female nested with another male in 1980–1981 and goslings were sighted.

Adults and young moved less than 0.1 km (0.06 mi) within the small *kīpuka* where the nest was located on day 1 (Figure 6). By day 4, one young had died, Crater Rim Drive had been crossed at least once, and the family was 1.2 km (0.7 mi) from the nest site. By day 6, the family had returned to the nest *kīpuka* across Crater Rim Drive, but by day 7 they had crossed Crater Rim Drive again. By the 11th day (12 March) only one young remained, and by day 14 (15 March), no young were present with the adults. The two young that survived past day 4 did not seem to be growing much and we predicted that they would not survive.

Distances between successive fixes from 12 March to 24 March ranged from less than 0.2 to 0.7 km (0.1–0.4 mi). By 8 April (38th day)

the male crossed Crater Rim Drive and was seen near the nest (without the female) 3.3 km (2.1 mi) from the previous fix. By 13 April (day 42), the male had crossed Crater Rim Drive again and was found to be in heavy molt 2.8 km (1.7 mi) from the previous location. The female was absent on this date and again on 15 April (day 45) when the male was located. By 27 April (day 56), the gander had crossed Crater Rim Drive again and was seen with the female 1.1 km (0.7 mi) from the previous location. On 20 May (day 79) the male was seen with the female from Family 11, and on 28 May (day 87) the male from Family 5 and the female from Family 11 (with her two fledglings) were observed near the Volcano Golf Course driving range 3.7 km (2.3 mi) from the 20 May sighting. The female from Family 5 was later associated with the male at the golf course.

#### DISCUSSION AND RECOMMENDATIONS

The limitations of this study are that only three *nene* families were followed in one area, during one year. Also, radio fixes were not as frequent as we had hoped. On the other hand, *nene* were tracked through a portion of the annual cycle about which not much was previously known in a currently important breeding area. Several points seem worth further study and management consideration:

1. In this study, predation was not a significant factor, yet recruitment rate was very low and mortality of eggs, young, and even adults was high. Desertion accounted for much of the egg mortality. (Two of six adults died of unknown causes, one prior to molt on Kapapala Ranch and one during molt near Halemaumau Pit; five of seven goslings in radio-tracked families died at the following ages: 1–4 days, 7–11 days, 11–14 days, 5–17 days, and 64–69 days.) Nutritional deficiencies may have been responsible for two gosling deaths and inclement weather for another, but this is uncertain. Early nesting success may be important for survival of goslings. The only young to survive in this study were produced early in the nesting season. Age and experience of breeding *nene* and pair bond longevity may

also play a role, as shown recently by Cook, Bousfield, and Sadura (1981) for lesser snow geese, *Anser caerulescens*.

2. Certain areas appear to be very important to *nene* survival and many are man-made. The lush pastures of Kapapala Ranch may provide better food for broods than is available in the park. Families 11 and 4 both crossed Highway 11 at about the same location, and this may be an important movement corridor. The Volcano Golf Course, Kipuka Kahali'i, Ainahou Ranch (southeast of the Ka'u Desert in the park), and Kapapala Ranch are important concentration areas for *nene* between the molting period and breeding season, based on information gathered in the summers of 1981–1982. Perhaps the area south of Keanakakoi Crater used during the molt by Families 11 and 5 is important to molting birds. High-use sites and movement corridors should be better identified and protected.

3. Even though *nene* are secretive when they have young broods, and especially during molt, they may travel long distances and frequent a large area. Prevention of disturbances such as harassment by dogs and people over a large area may be as important when adults and young are physically and physiologically vulnerable as it is early in the nesting season.

4. Release sites are very important determinants of future breeding sites for HAVO geese (females). All nine of the nest sites chosen in the past 2 years by HAVO females released in the lowlands were in the lowlands. All were very close to natal pens and three were within release pens. Similarly, Ka'u Desert sites were chosen by HAVO females released at mid-elevation sites. Release sites should be chosen where survival and breeding potentials are high, or management should be intensified in release areas. Larger numbers than the present average of seven birds per year should probably be released to ensure that some survive and return.

5. The effects of the researcher on the birds under study should continue to be scrutinized. Two of four instrumented animals died during the study, one during a period of stress (molt). We noted no unusual weight loss or preoccupation with harnesses or radios of instrumented birds, although weight loss during

molt for some instrumented and uninstrumented birds is severe. It seems unlikely that stress caused by light-weight radios is significant, but it is possible where birds are severely stressed otherwise. The information to be gained from radio-tracking is, at present, worth some risk, in our judgment.

6. *Nene* readily form pairs, but the percentage of birds that do not even appear to attempt nesting in the wild is alarming. Whether the cause is genetic, physiological, behavioral, nutritional, or a combination of these, remains to be determined. The number of *nene* pairs that do not attempt to breed is probably a more important determinant of population levels and stability than other negative impacts on recruitment such as predation. It is surely a significant influence on genetic variation. Efforts to determine solutions to this problem should be increased.

#### ACKNOWLEDGMENTS

We appreciate the help of a number of people who assisted us in locating nests and in radio-tracking birds. Included are V. Collins, D. B. Fellows, S. Fellows, P. K. Higashino, R. Keahulua, G. Moses, E. J. Stone, M. E. Stone, W. Taka, and J. Toriano. W. Taka trapped mongooses and D. Kageler took the photograph in Figure 2. I. H. Nicola drafted the figures. We especially thank D. B. Fellows for typing the manuscript.

#### LITERATURE CITED

- BALDWIN, P. K. 1945. The Hawaiian goose, its distribution and reduction in numbers. *Condor* 47(1):27-37.
- BANKO, P. C. 1982. Productivity of wild and captive nene populations. *Proc. Hawaii Volcanoes Natl. Park Nat. Sci. Conf.* 4:12-32.
- DOTY, M. S., and D. Mueller-Dombois. 1966. Atlas for bioecology studies in Hawaii Volcanoes National Park. *Hawaii Bot. Sci. Paper* 2. 507 pp.
- COOK, F., M. A. BOUSFIELD, and A. SADURA. 1981. Mate change and reproductive success in the lesser snow goose. *Condor* 83(4):322-327.
- HENSHAW, H. W. 1902. Complete list of the birds of the Hawaiian possessions, with notes on their habits. T. G. Thrum, Honolulu.
- LIEBERMAN, G. A. 1973. Design of a tracking and observation study for small mammal studies. *Canadian Field Nat.* 87(4):455-456.
- MUELLER-DOMBOIS, D. 1976. The major vegetation types and ecological zones in Hawaii Volcanoes National Park and their application to park management and research. *Proc. Hawaii Volcanoes Natl. Park Nat. Sci. Conf.* 1:149-161.
- OLSON, S. L., and H. F. JAMES. 1982. Prodrum of the fossil avifauna of the Hawaiian Islands. *Smithsonian Contrib. Zool.* 365.
- PERKINS, R. C. L. 1903. Fauna Hawaiiensis: Vertebrates (Aves). pp. 368-465. *In* D. Sharp, ed. *Zoology of the Sandwich (Hawaiian) Islands*. Vol. I, pt. IV. Cambridge University Press, Cambridge.
- WALKER, R. L. 1982. State of Hawaii nene propagation ... past, present, and future [abstr]. *Proc. Hawaii Volcanoes Natl. Park Nat. Sci. Conf.* 4:185.